Seasonal-interannual prediction of ecosystems and the global carbon cycle using NCEP/CFS

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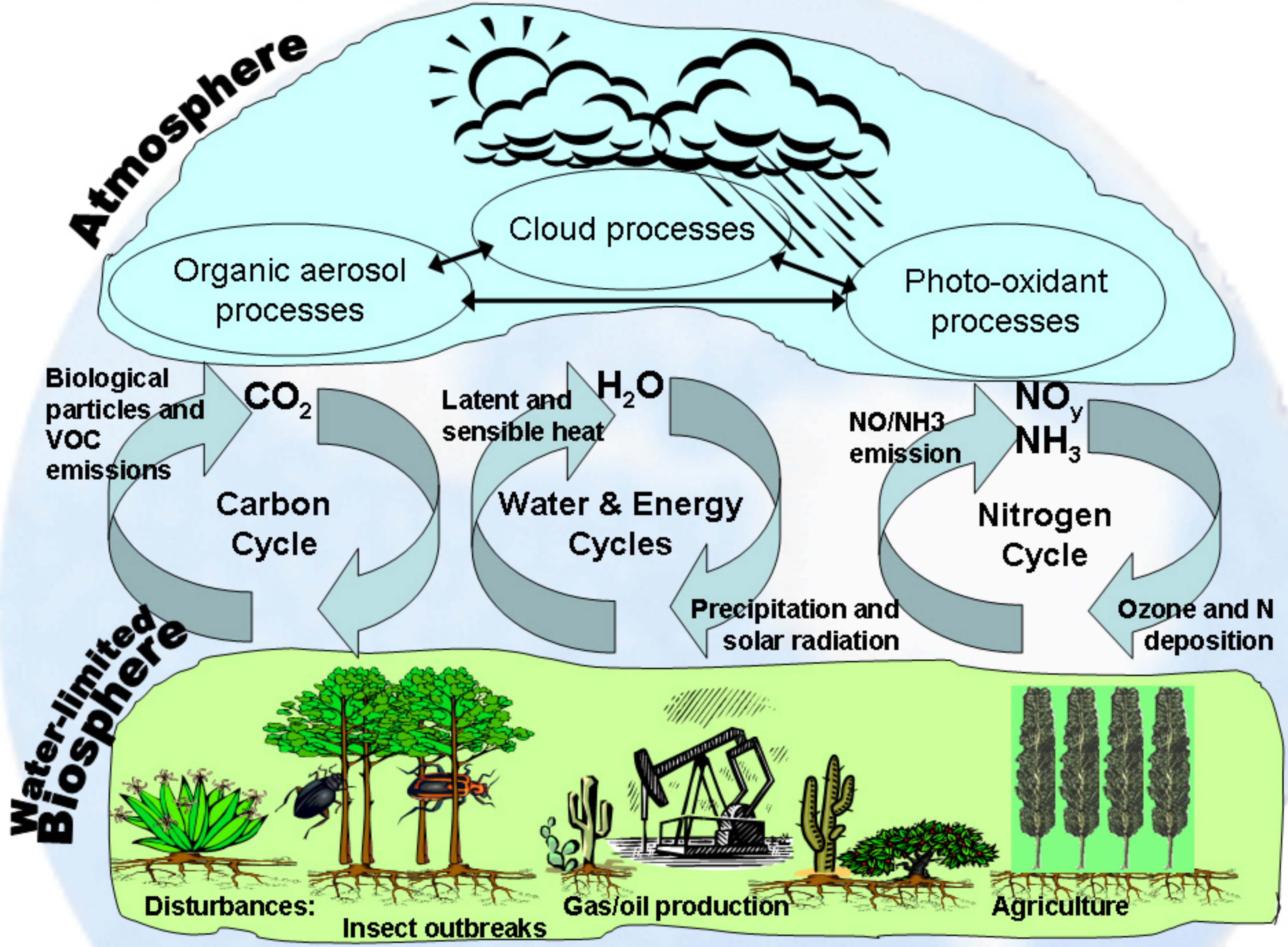
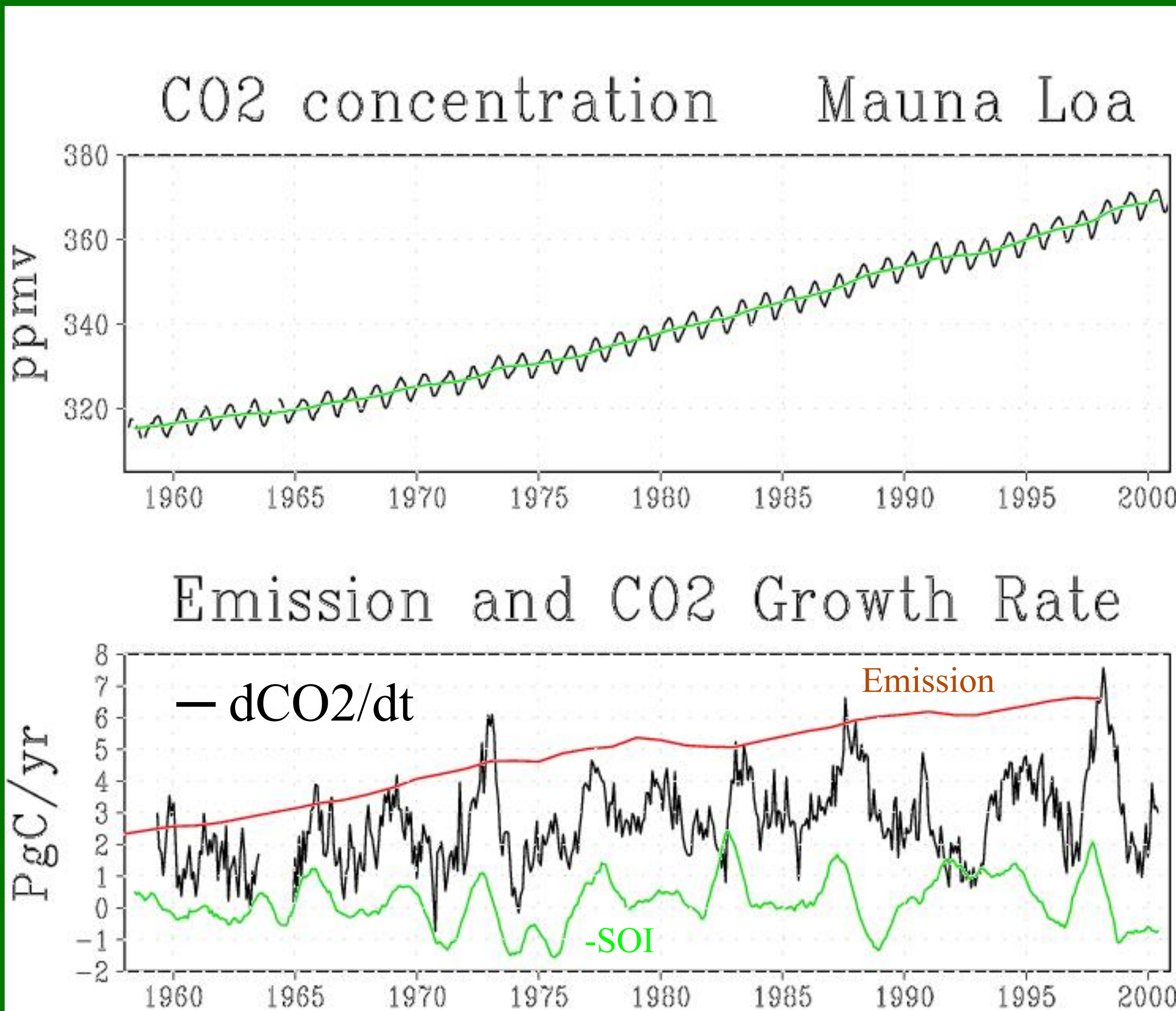
Bio-hydro-atmosphere interactions of Energy, Aerosols, Carbon, H_2O, Organics and Nitrogen



Why predicting eco-CO2: targets

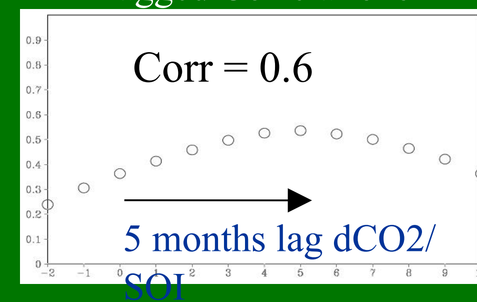
- Predicting atmospheric CO2 concentration and growth rate. Atmospheric CO2 can be a ‘climate index’ indicating anomalies in the global ecosystem
- Predict spatial patterns and temporal variability of carbon fluxes and pool size ➔ Example: biosphere productivity, fire, CO2 flux, crop harvest
- Stepping stone for Earth system analysis and modeling
- Including vegetation dynamics to improve short-term climate prediction, such as warm season US?
- In a carbon trading market, there will be a strong need for monitoring and anticipating the carbon pool changes

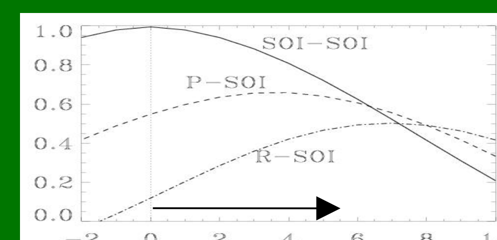
Foundation of dynamical eco-carbon prediction
CO_2 as a "climate index"



Seasonal cycle:
Northern Hemisphere biosphere growth and decay

Lagged Correlations





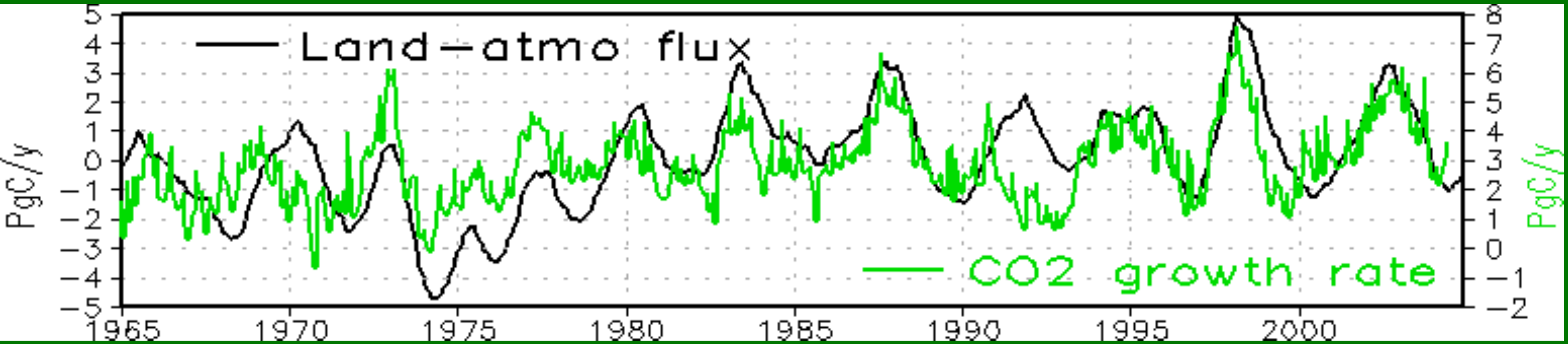
3-6 months lag Hydrology/SOI

Interannual variability:
ENSO, drought, fire, Pinatubo

Foundation of dynamical eco-carbon prediction

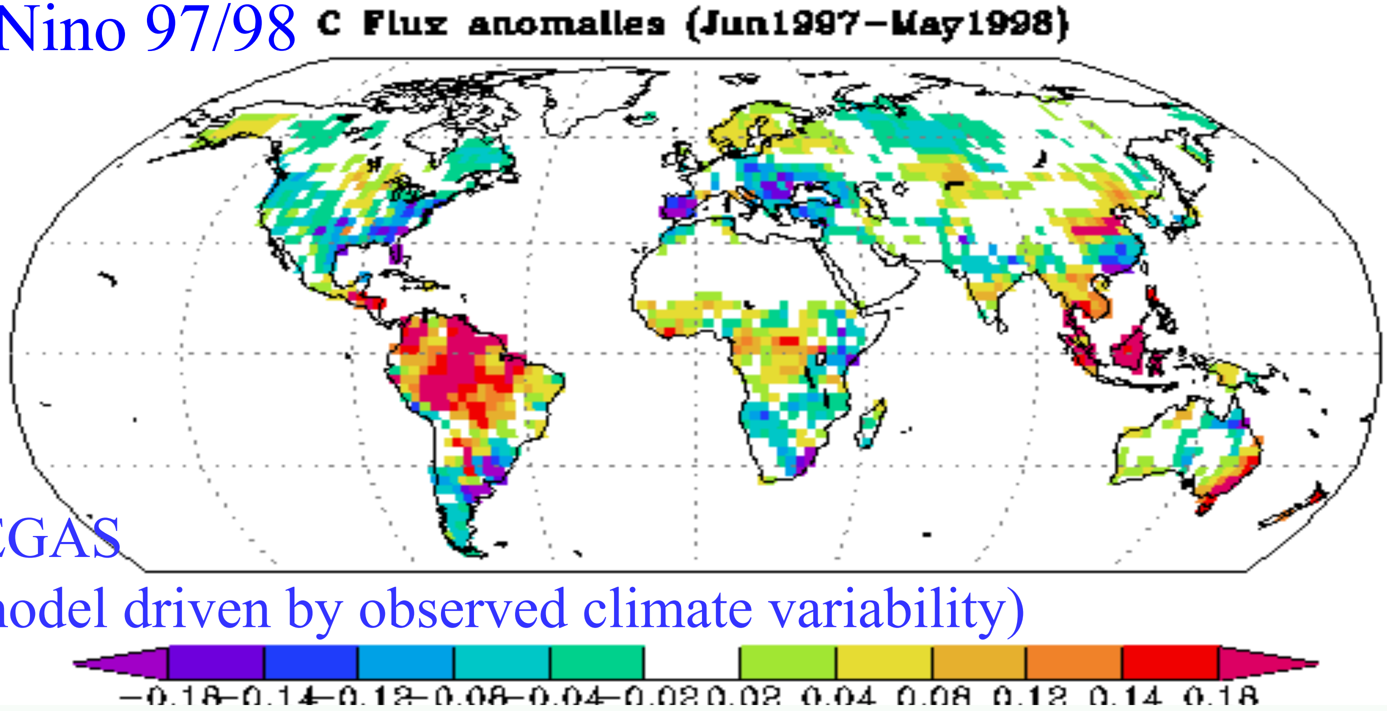
'Breathing' of the biosphere: CO_2 as a response to and an indicator of climate

Modeled land-atmo flux vs. MLO CO_2 growth rate

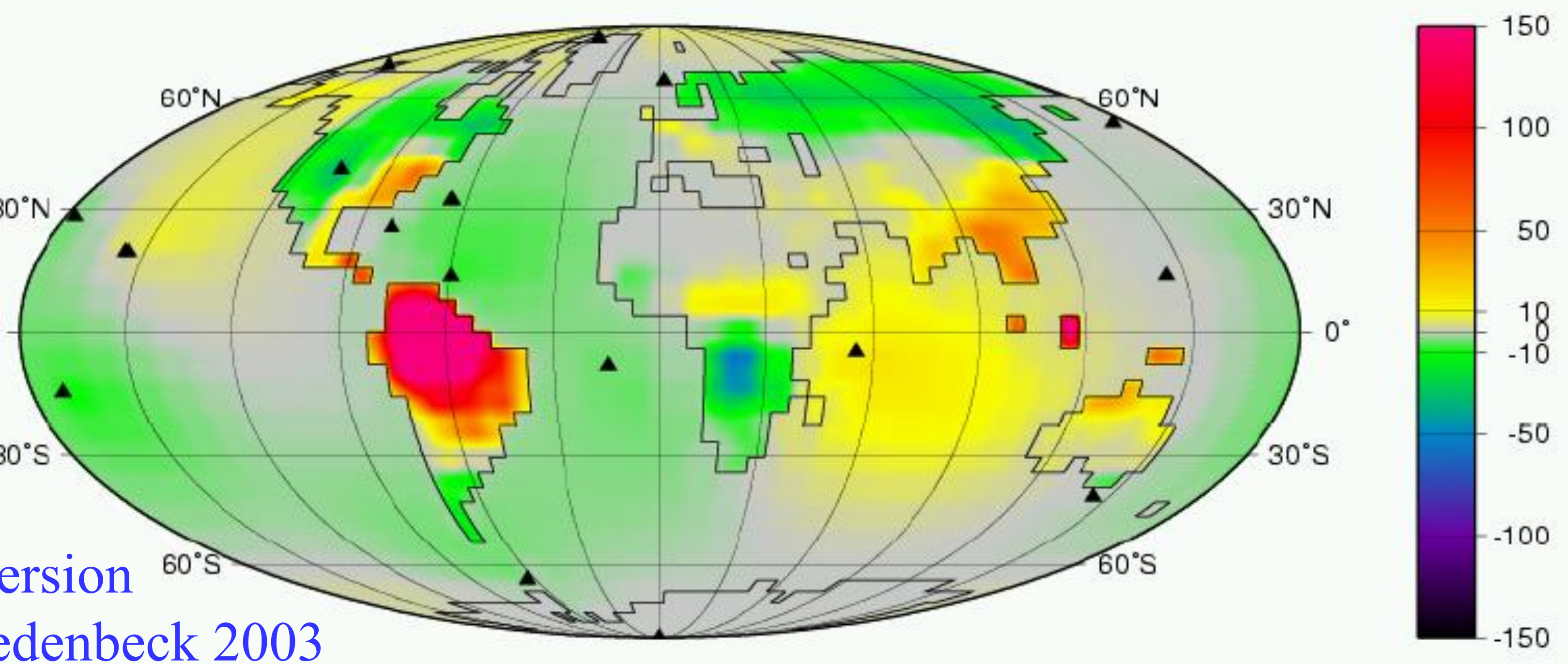


Seasonal-interannual CO_2 variability is largely driven by climate variability: ENSO, Pinatubo, drought and other signals

El Nino 97/98



VEGAS
(model driven by observed climate variability)



Inversion
Roedenbeck 2003

Seasonal-interannual Prediction of Ecosystems and Carbon Cycle

Made possible by two strands of recent research

- Significantly improved skill in atmosphere-ocean prediction system, such as NCEP/CFS and NASA/GMAO
- Development of dynamic ecosystem and carbon cycle models that are capable of capturing major interannual variabilities, when forced by realistic climate anomalies

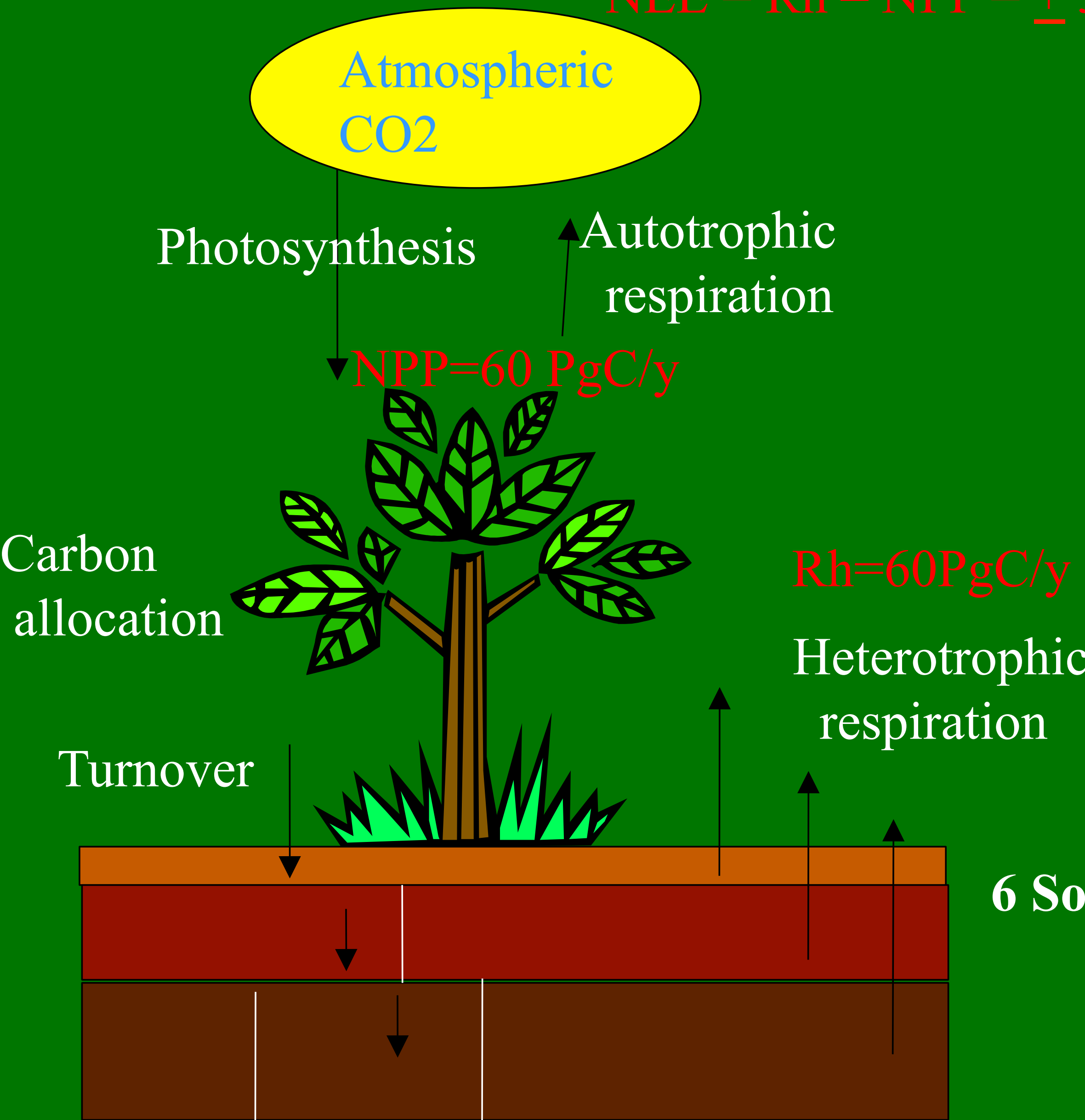
A pilot hindcast study joint at UMD, NCEP and NASA:

➔ Feasibility study using a prototype eco-carbon prediction system dynamical vs. statistical

N. Zeng, J. Yoon, A.Vintzileos, G. J. Collatz, E. Kalnay, A. Mariotti,
A. Kumar, A. Busalacchi, S. Lord

The VEgetation-Global Atmosphere-Soil Model (VEGAS)

NEE = Rh – NPP = $\pm$ 3 (Interannual)



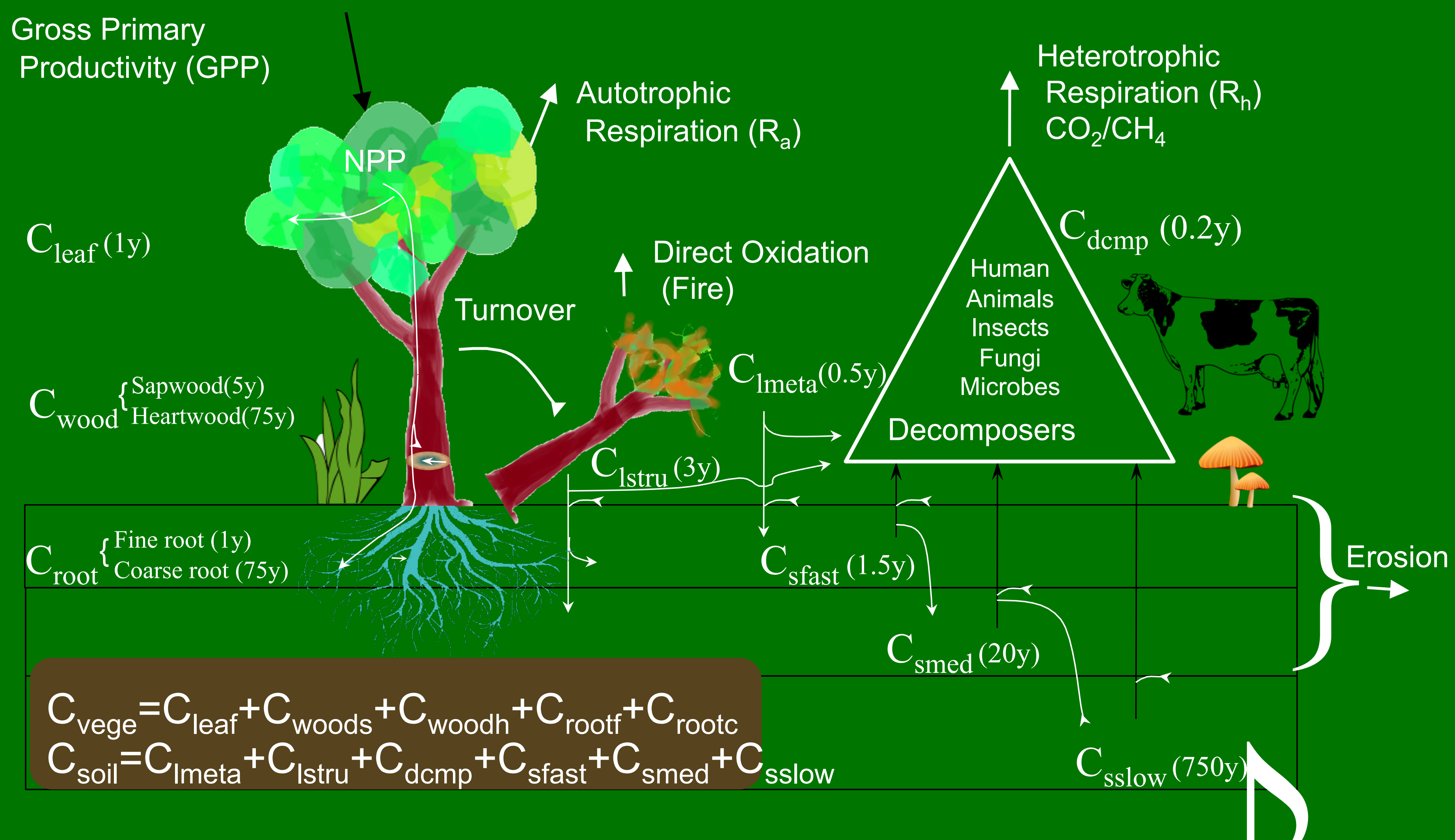
5 Plant Functional Types:
- Broadleaf tree
- Needleleaf tree
- C3 Grass (cold)
- C4 Grass (warm)
- Crop/grazing

Deciduous or evergreen is dynamically determined

5 Vegetation carbon pools:
- Leaf
- Root (fine, coarse)
- Wood (sapwood, heartwood)

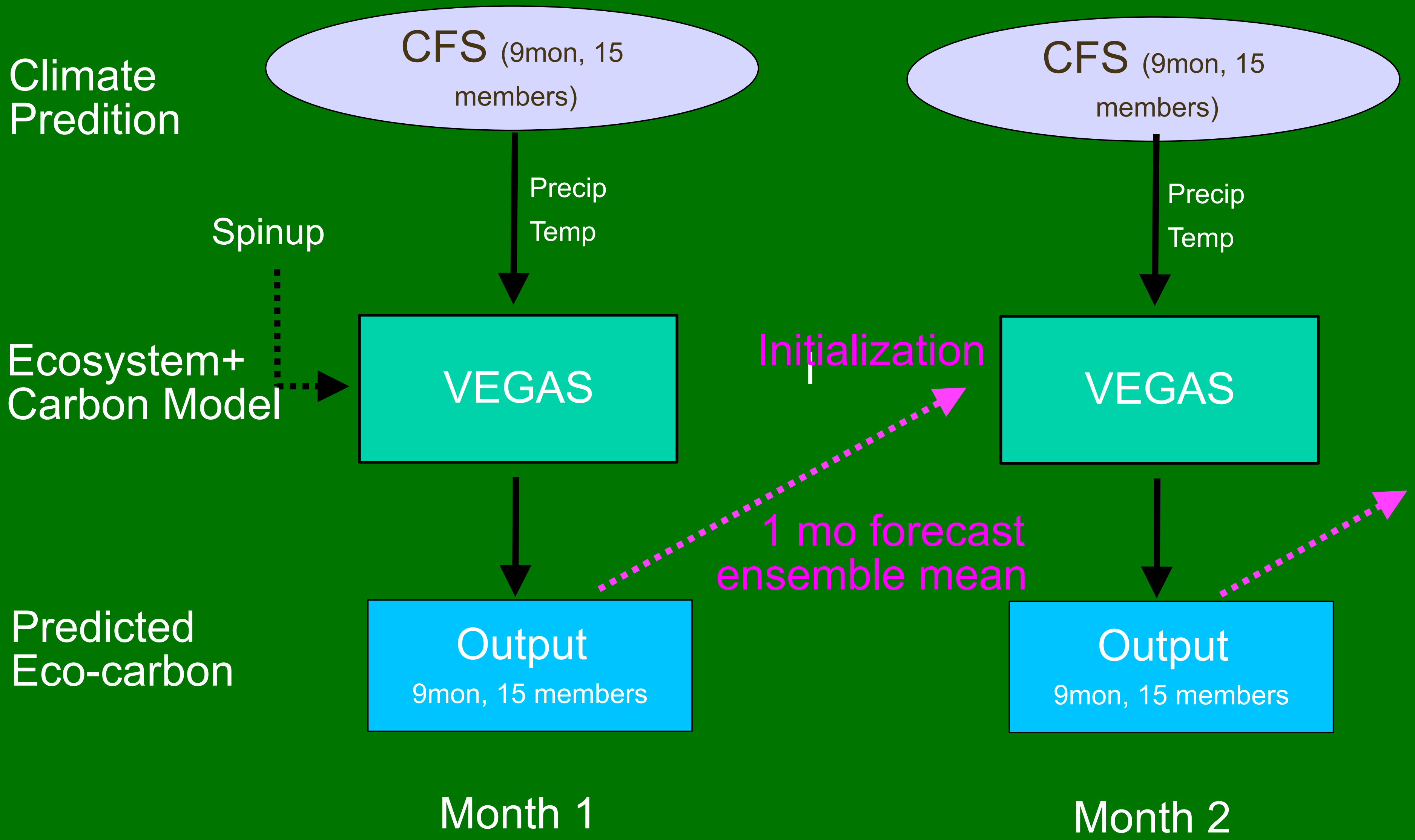
6 Soil carbon pools:
- Microbial
- Litterfall: metabolic, structural
- Fast, Intermediate, Slow

The VEgetation-Global Atmosphere-Soil Model (VEGAS)

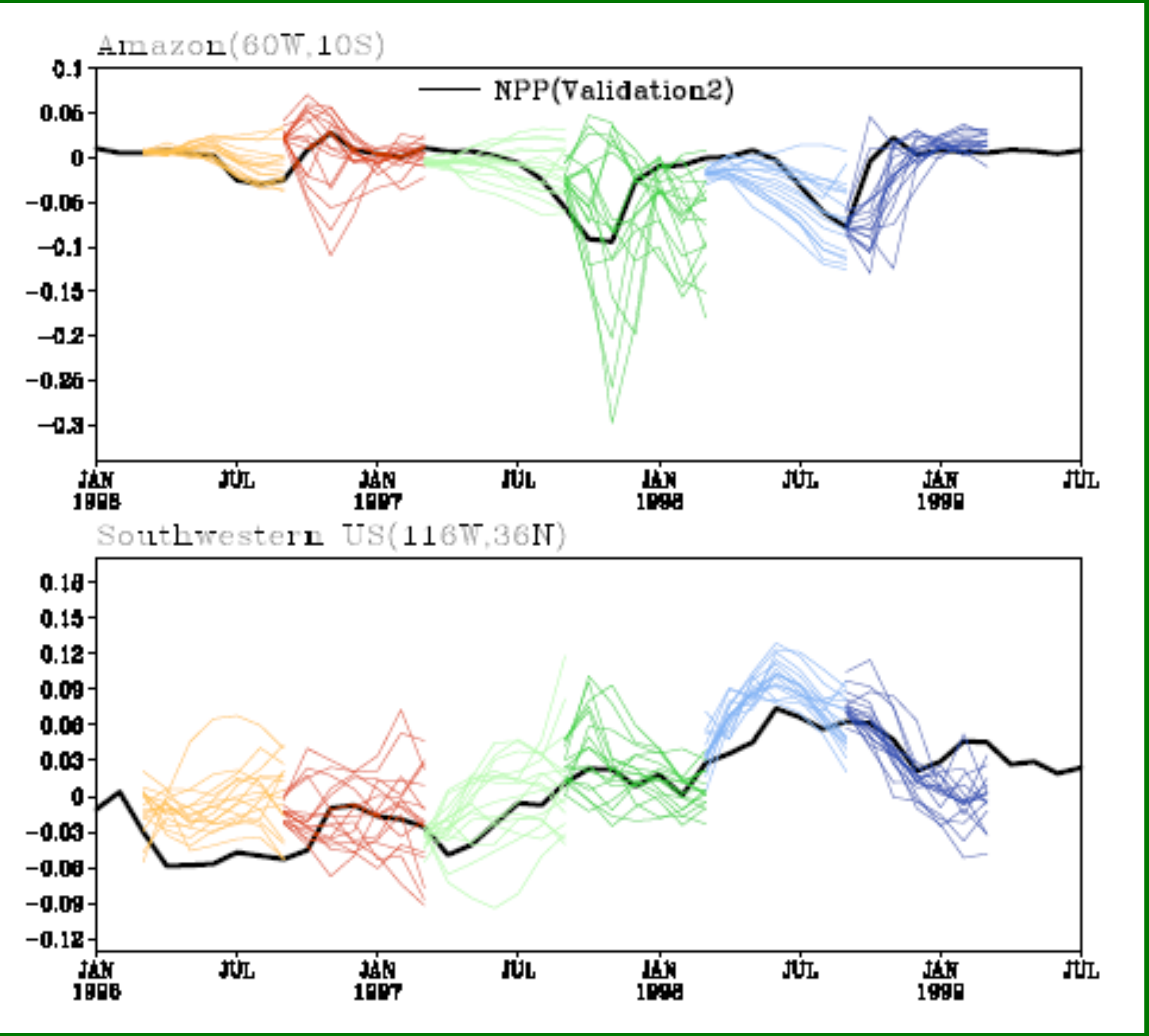


$$C_{vege}=C_{leaf}+C_{woods}+C_{woodh}+C_{rootf}+C_{rootc}$$
$$C_{soil}=C_{lmeta}+C_{lstru}+C_{dcmp}+C_{sfast}+C_{smed}+C_{sslow}$$

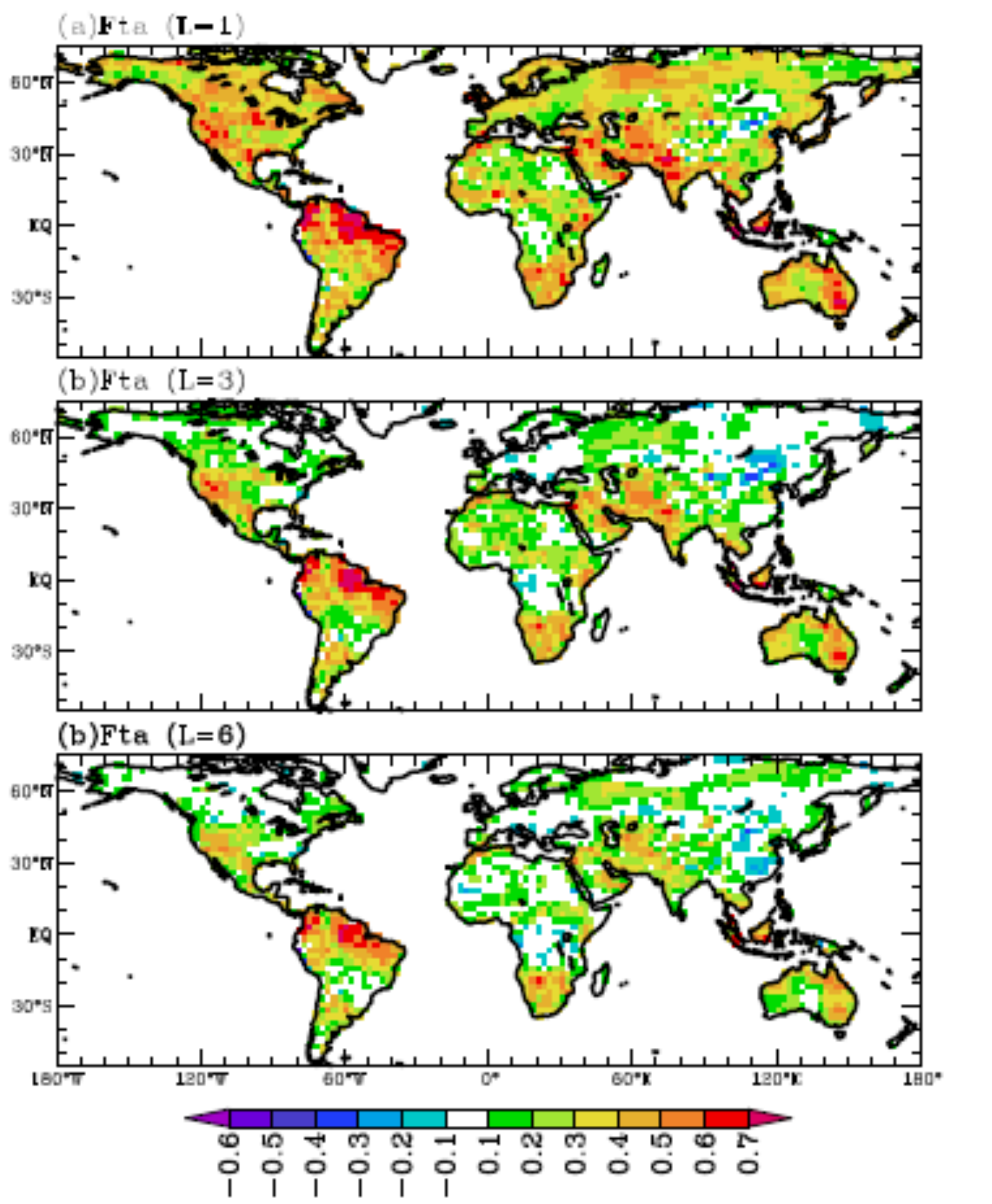
Forecasting Procedure I



First look: Productivity (NPP)



Anomaly Correlation Land-atmo carbon flux

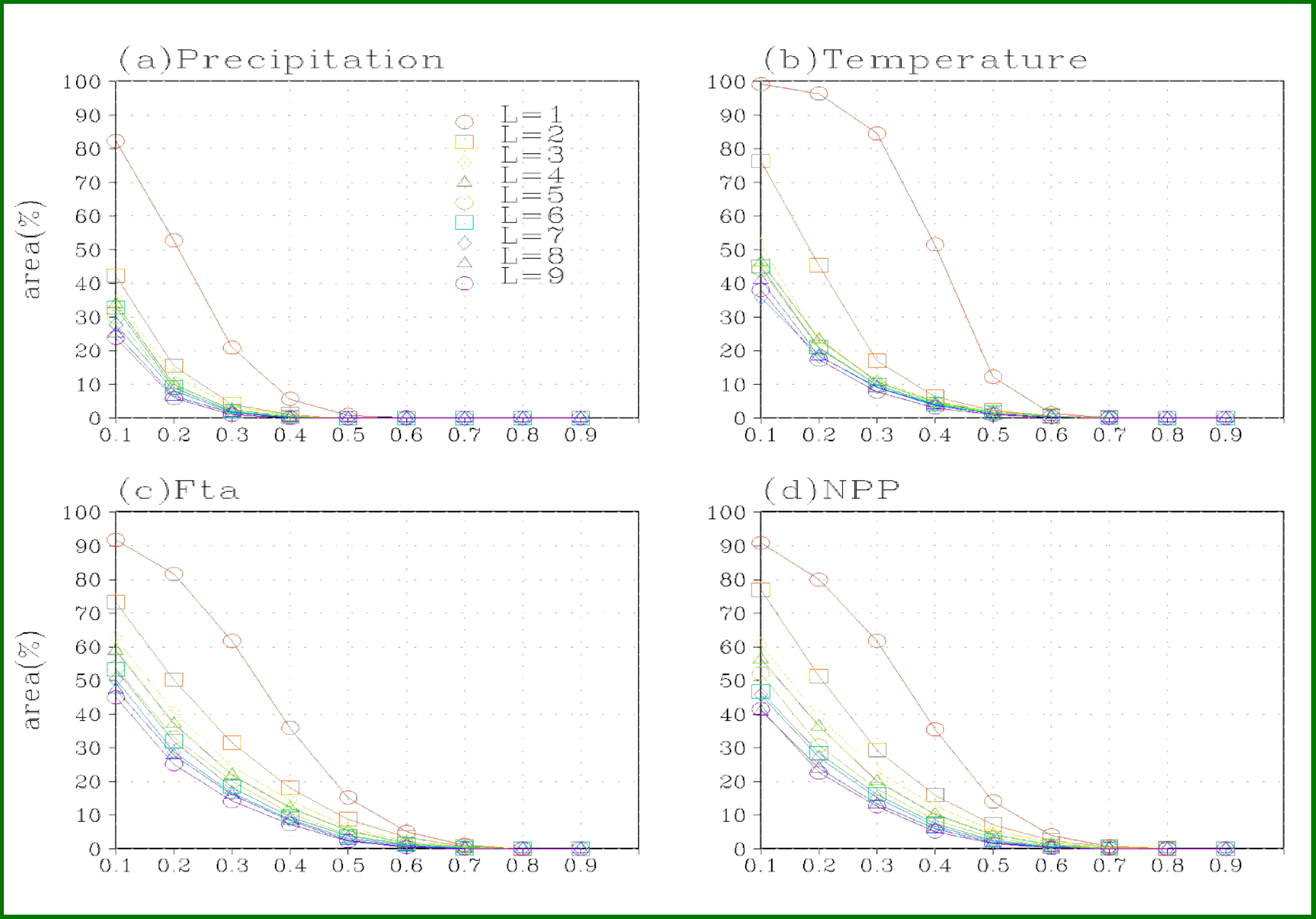


Lead times: 1, 3, 6 months

High skills in

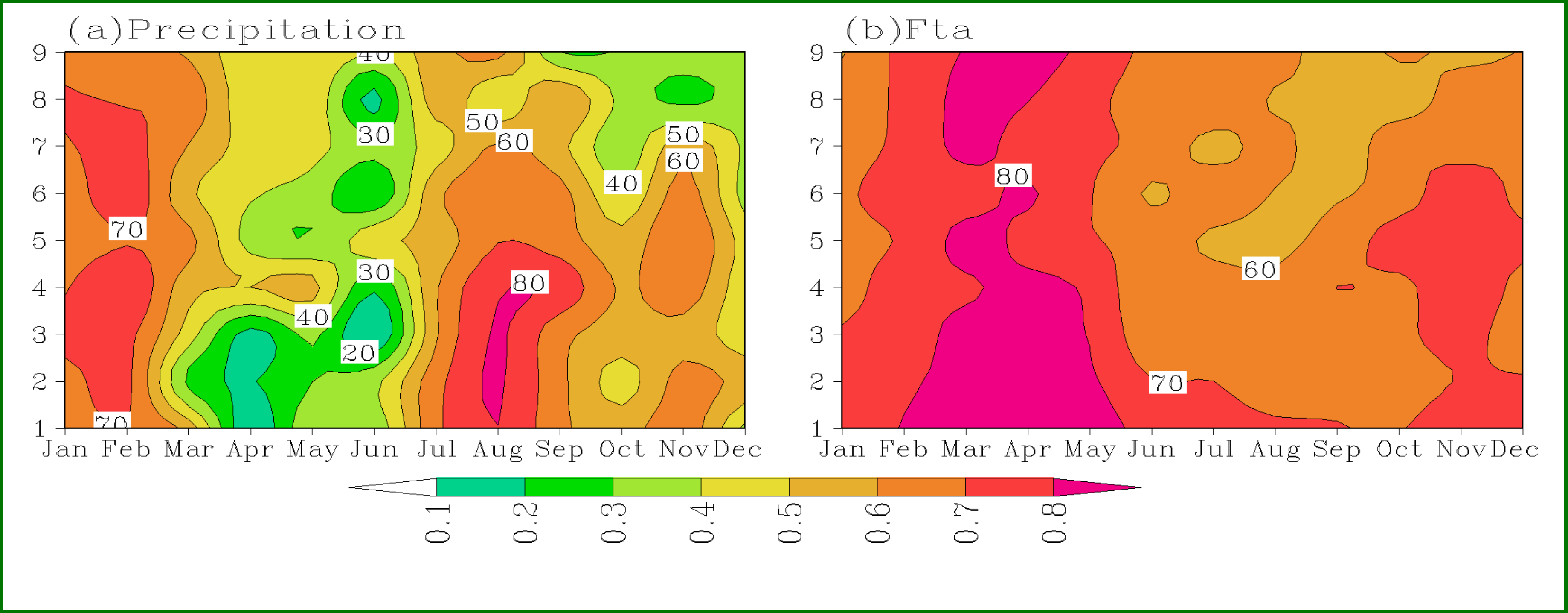
- South America
- Indonesia
- southern Africa
- eastern Australia
- western US
- central Asia

Summary of skill for anomaly correlation

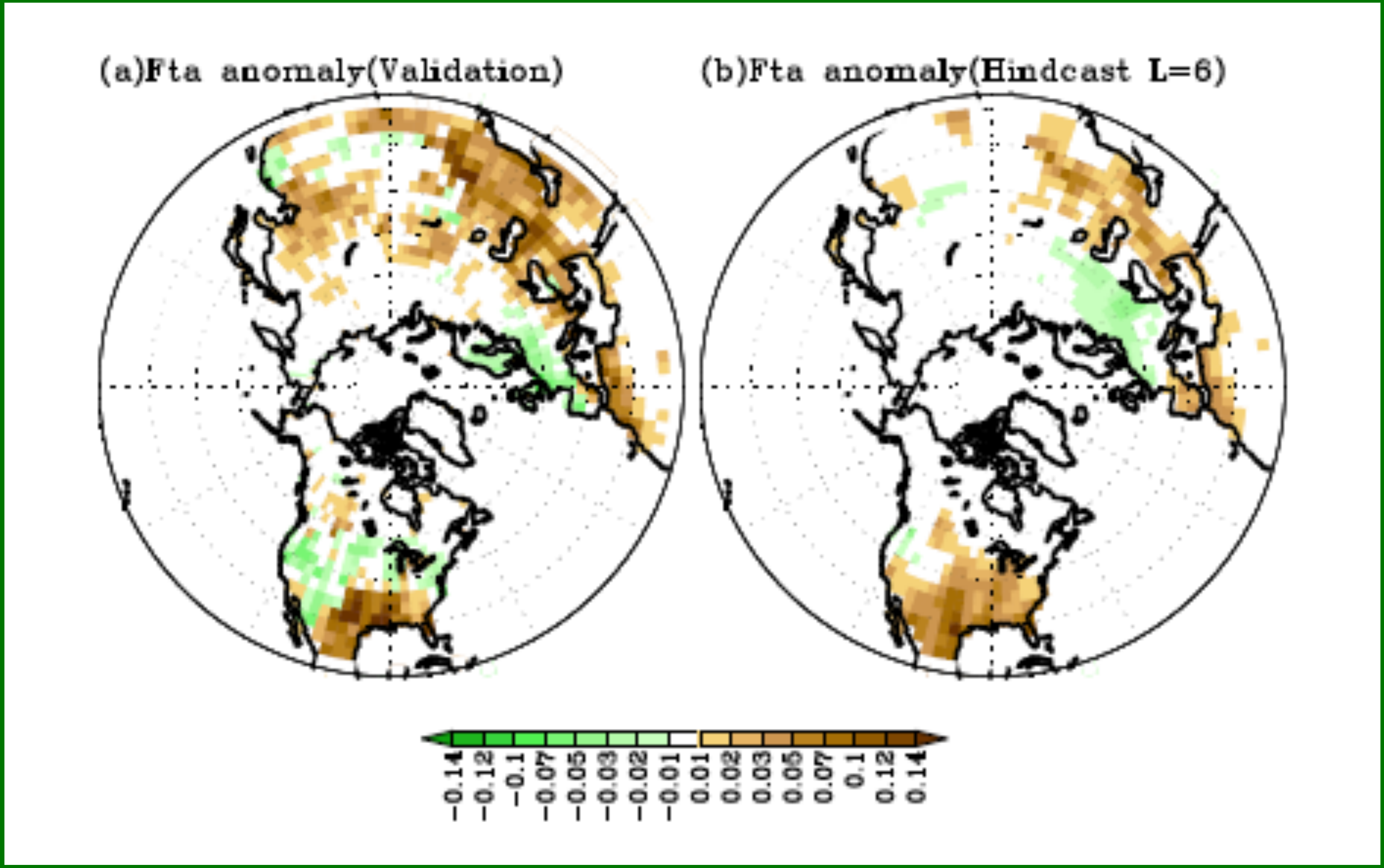


Hydroeco/carbon has higher skill than the climate forcings!

Summary of skill for anomaly correlation



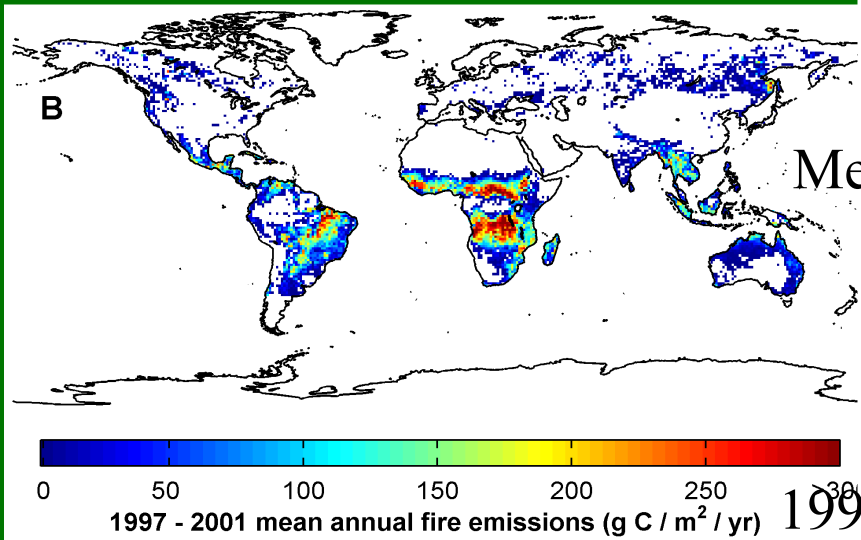
Beyond ENSO:
Drought during 1998-2002



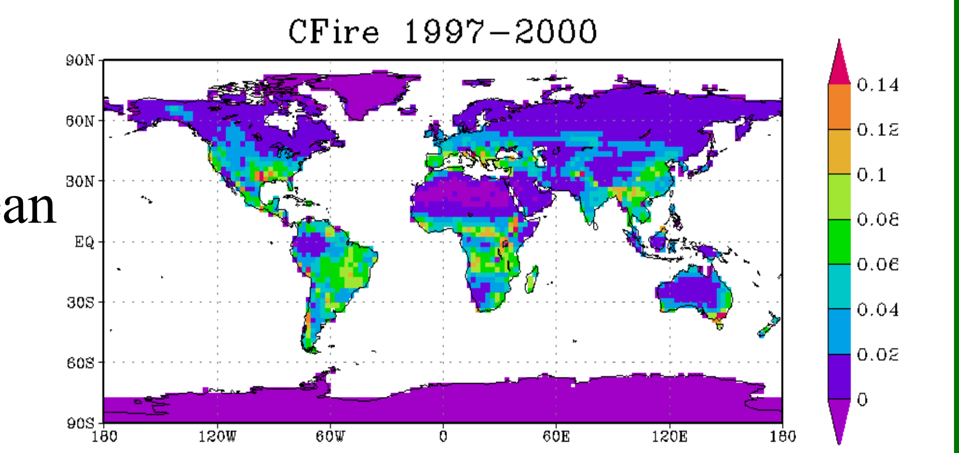
Fire carbon flux during 1997-98 El Nino

CASA (satellite fire, climate)

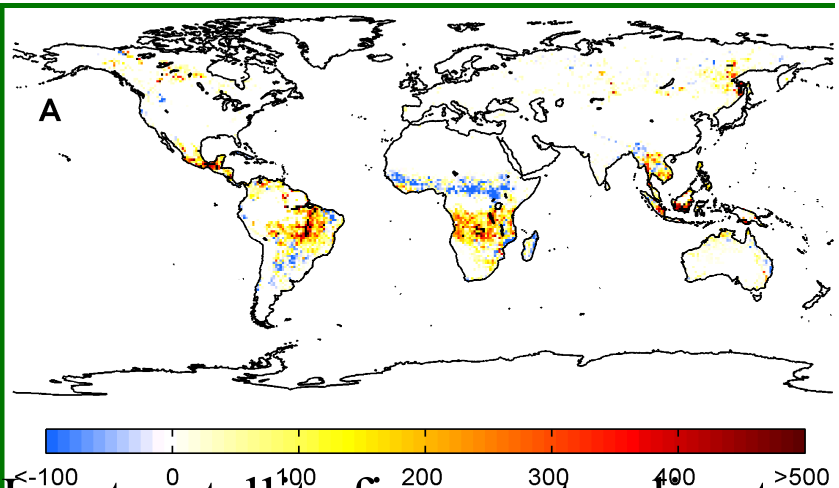
VEGAS (climate only)

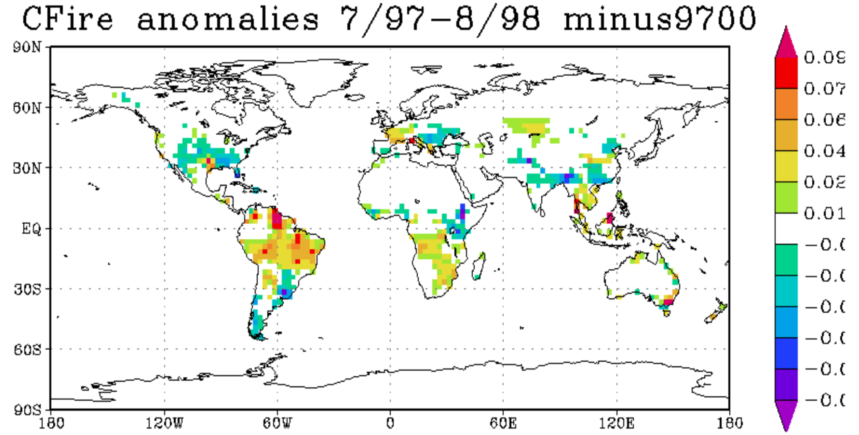


Mean



1997-98 El Nino Anomalies



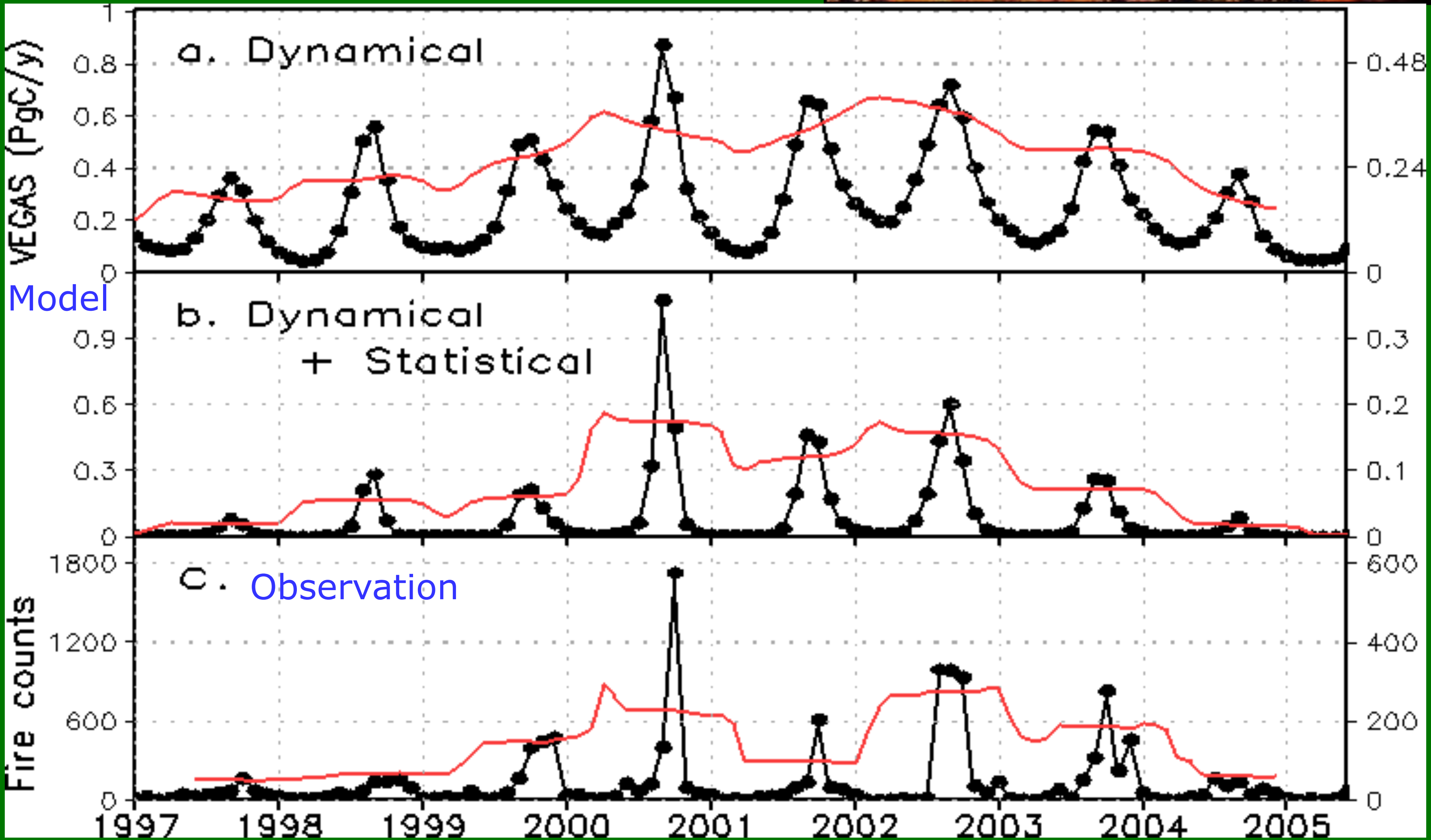


Input: satellite fire counts, climate

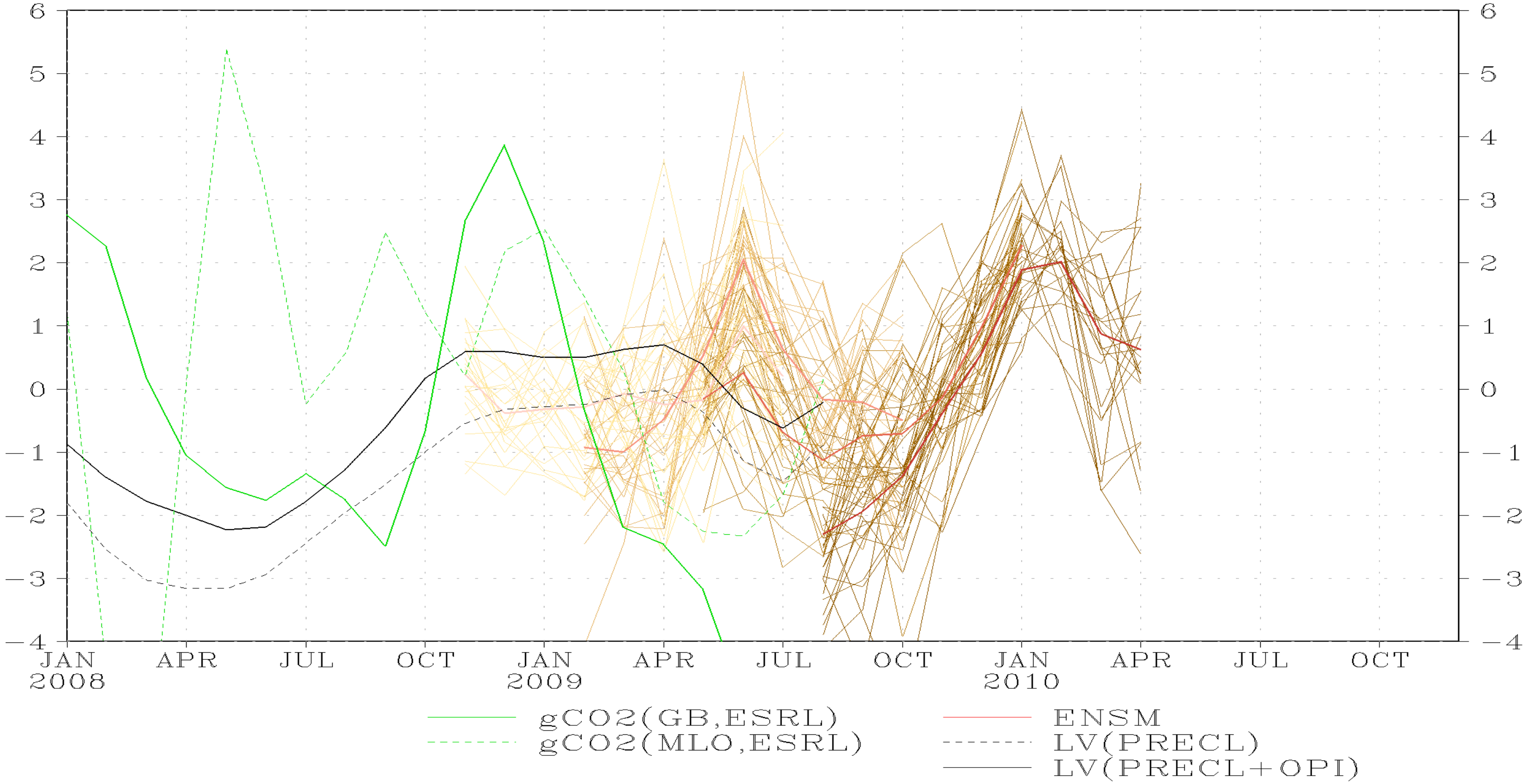
Input: climate only

Beyond ENSO: Fire in the US

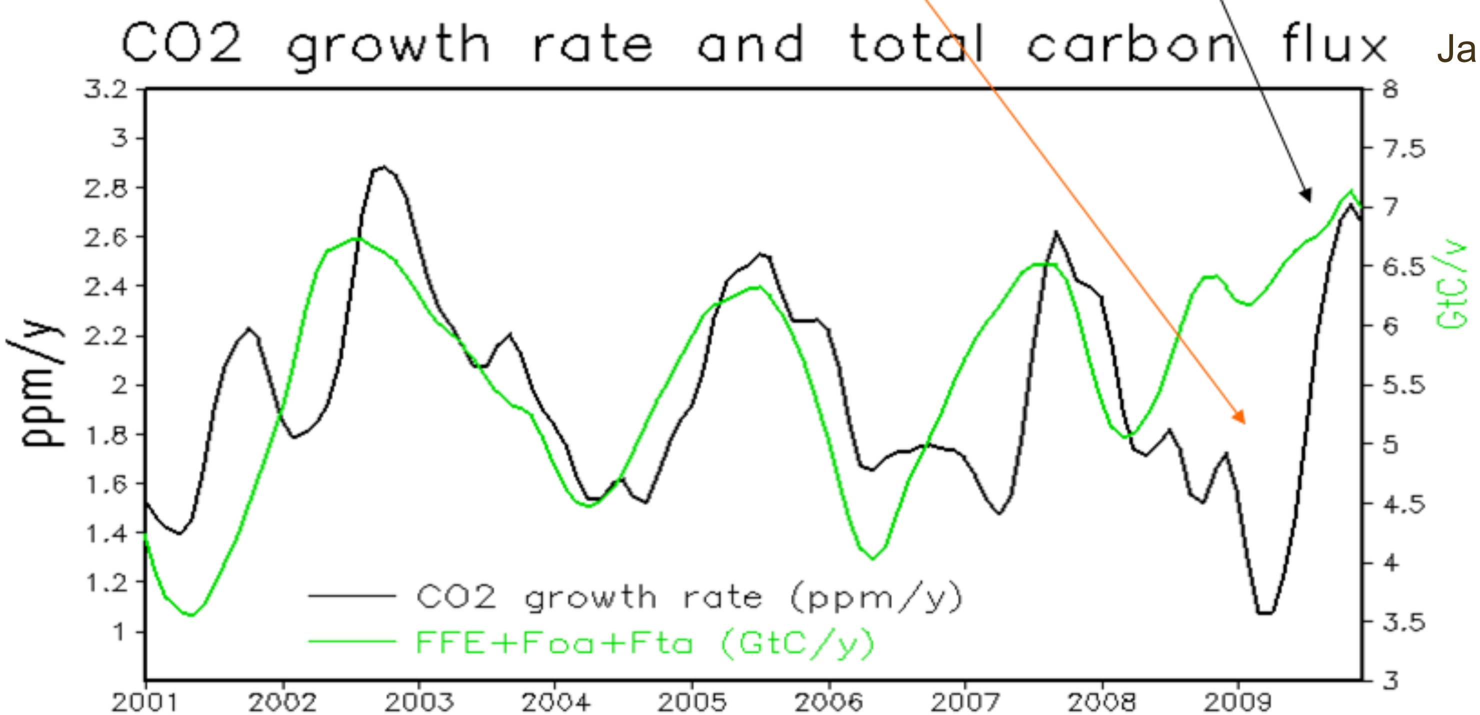
Natural and anthropogenic factors



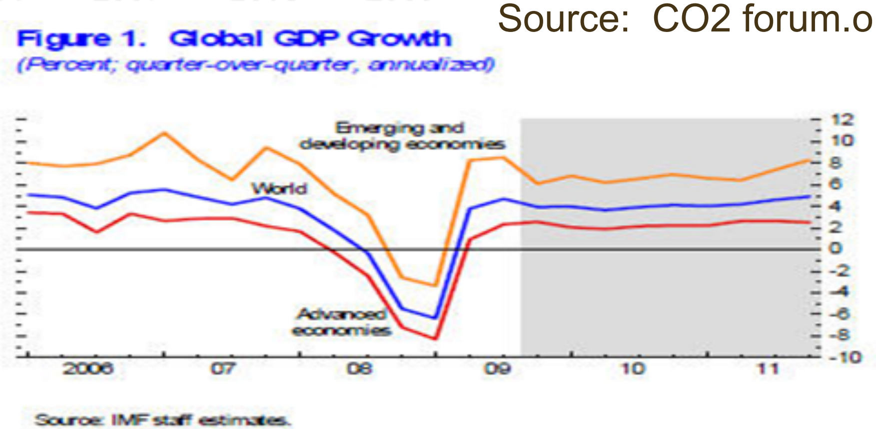
Pseudo-operational forecast



Economic downturn?   El Nino



Source: CO2 forum.org



Can the drop be caused by reduced FFE due to economic downturn?

An 8% drop in GDP/FFE can explain only 0.05 GtC/y (P. Tans, 2010), too small

So, the model doesn't get it?

Conclusions

- Ecosystem and carbon cycle prediction is feasible: encouraging results (better than expected)
- Memory in the hydro-ecosystem is important in the enhancement of skill
- several issues such as overestimation at mid-latitude regions

Some major development needs

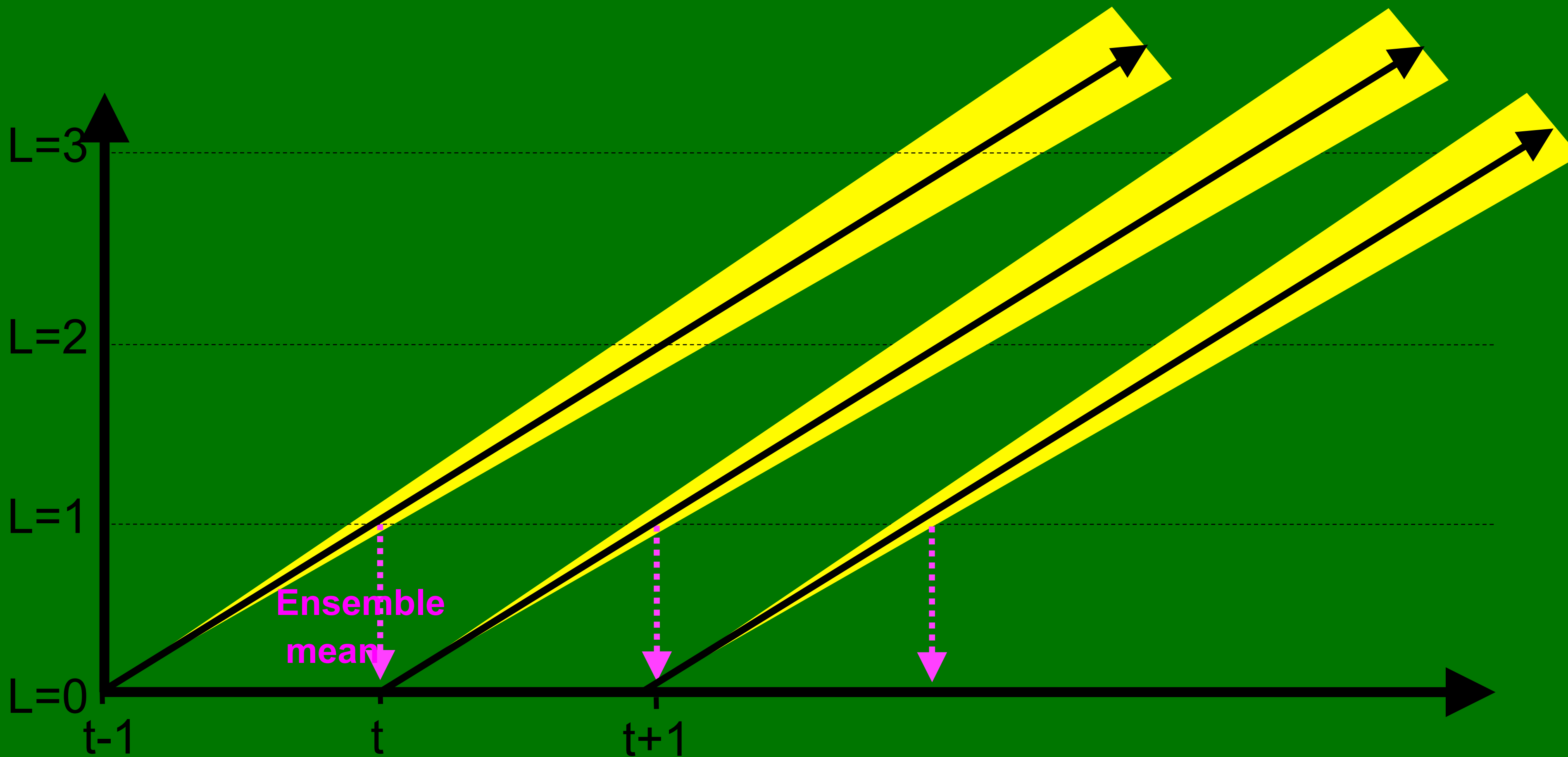
- Initialization: eco-carbon data assimilation?
  - Lack of global eco/carbon data
- Preprocessing/downscaling/postprocessing
- Dynamical + statistical
- Operational

Implications for climate service

- Applications to ecosystem and carbon cycle
- Identifying more clearly society-relevant aspects
- A useful framework for studying eco-carbon response and feedback to climate
- Identifying ways to incorporate eco-carbon dynamics in the next generation of climate prediction models (European GEMS)

Thank you!

Forecasting procedure II



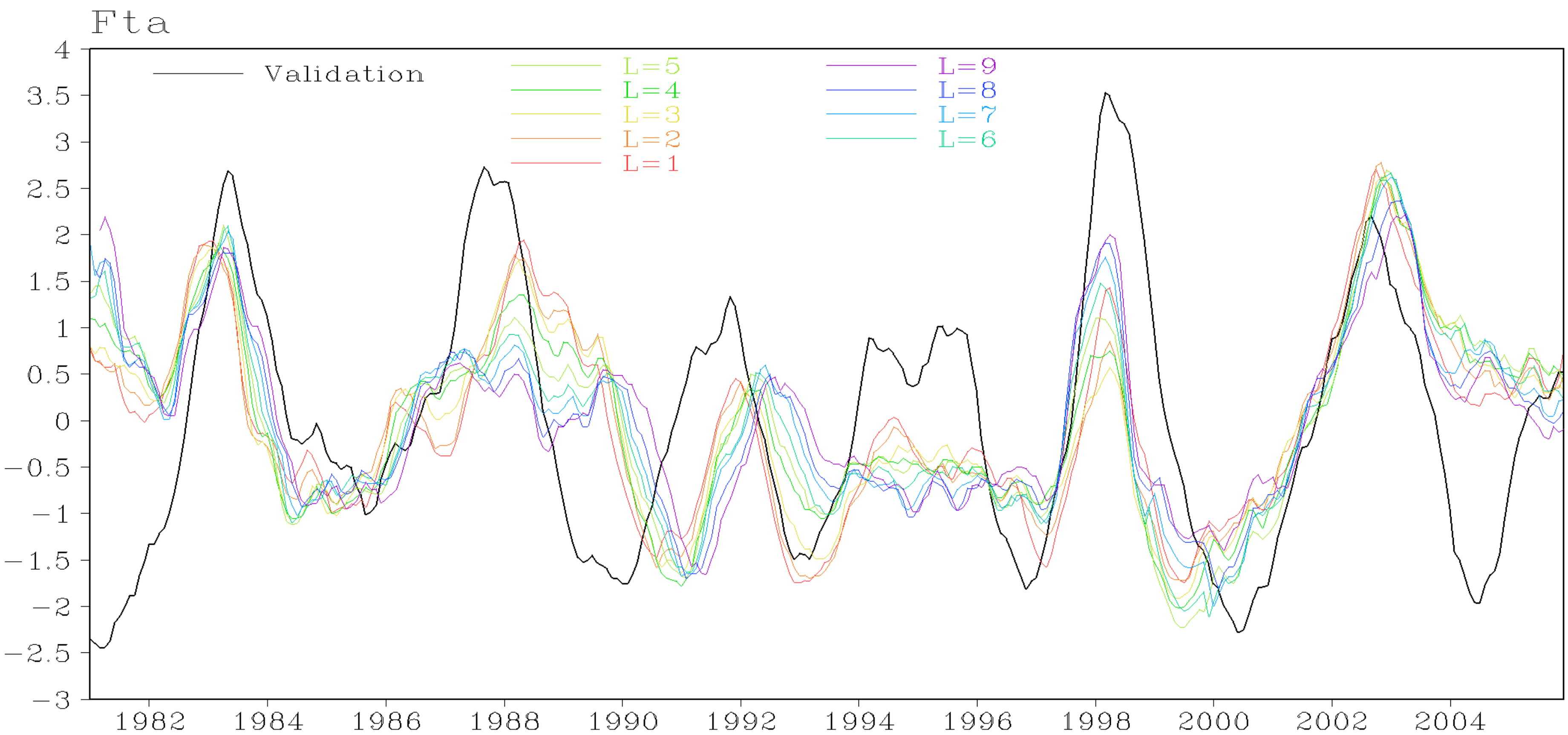
Implications of prediction

- Applications to ecosystem and carbon cycle

- A new framework for study eco-carbon response and feedback to climate

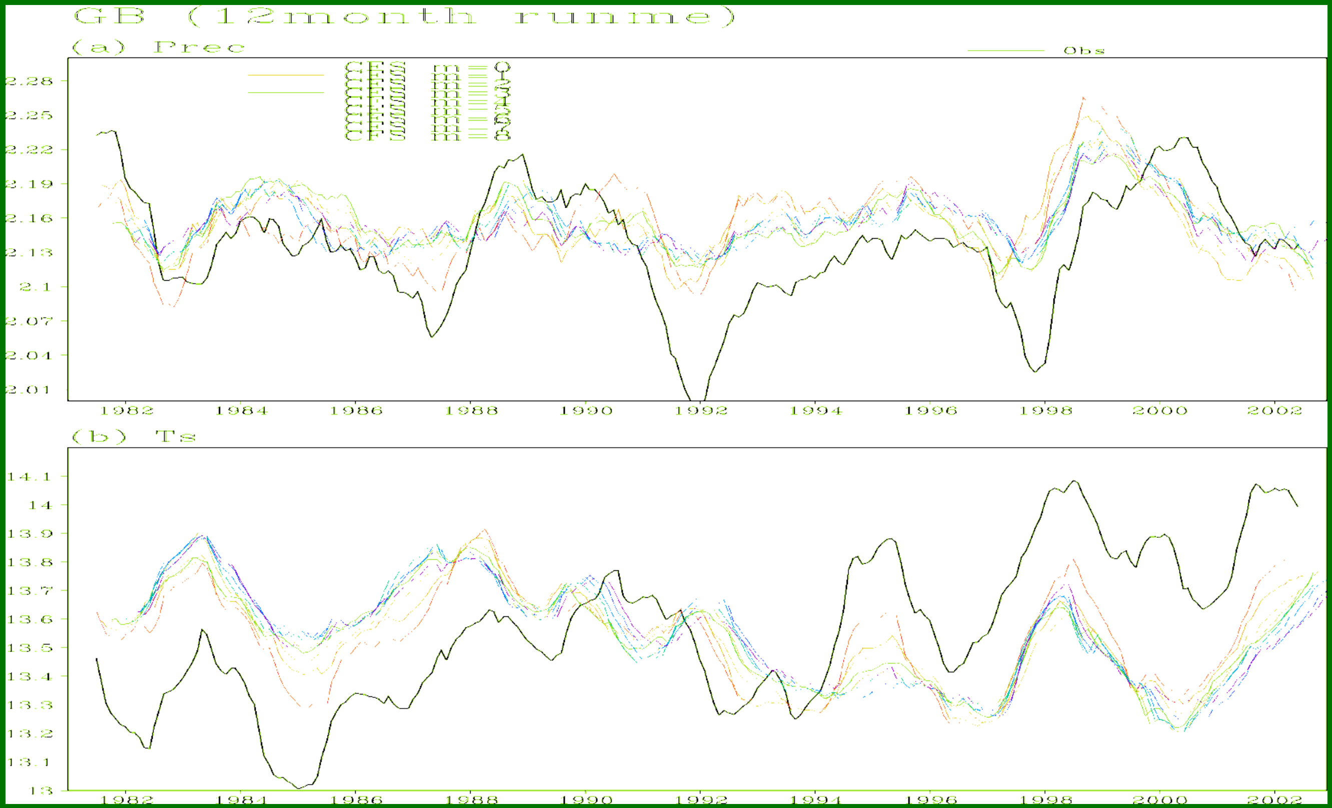
- Identifying ways of incorporating eco-carbon dynamics in the next generation of Earth system prediction models

Predicted global cabon flux (Fta)



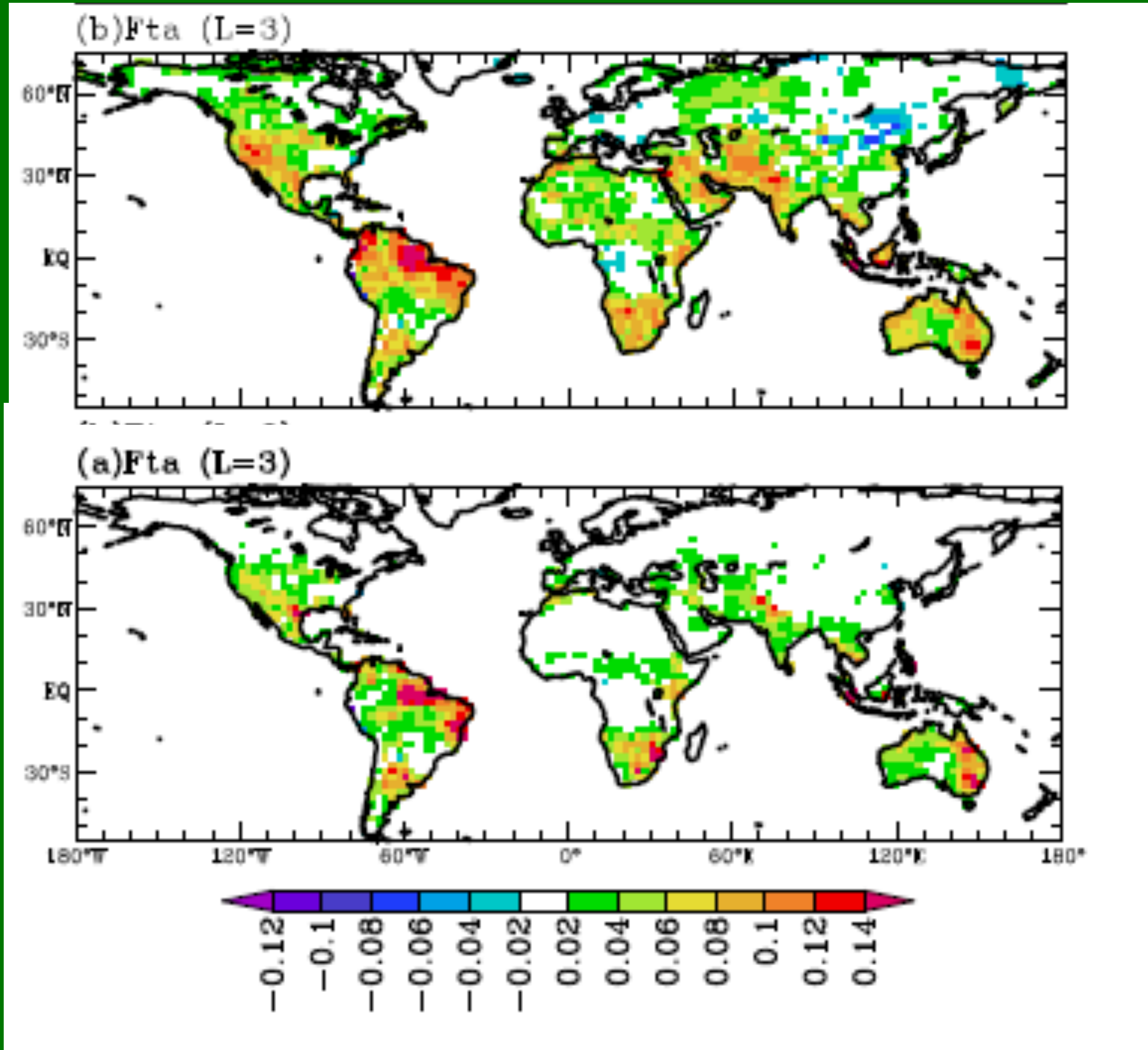
1. CFS/VEGAS captures most of the interannual variability, but
2. Amplitude is underestimated

The NCEP Climate Forecast System (CFS, Saha et al. 2006)



CFS captures major ENSO and other seasonal-interannual variability

Correlation .vs. Regression (Amplitude)

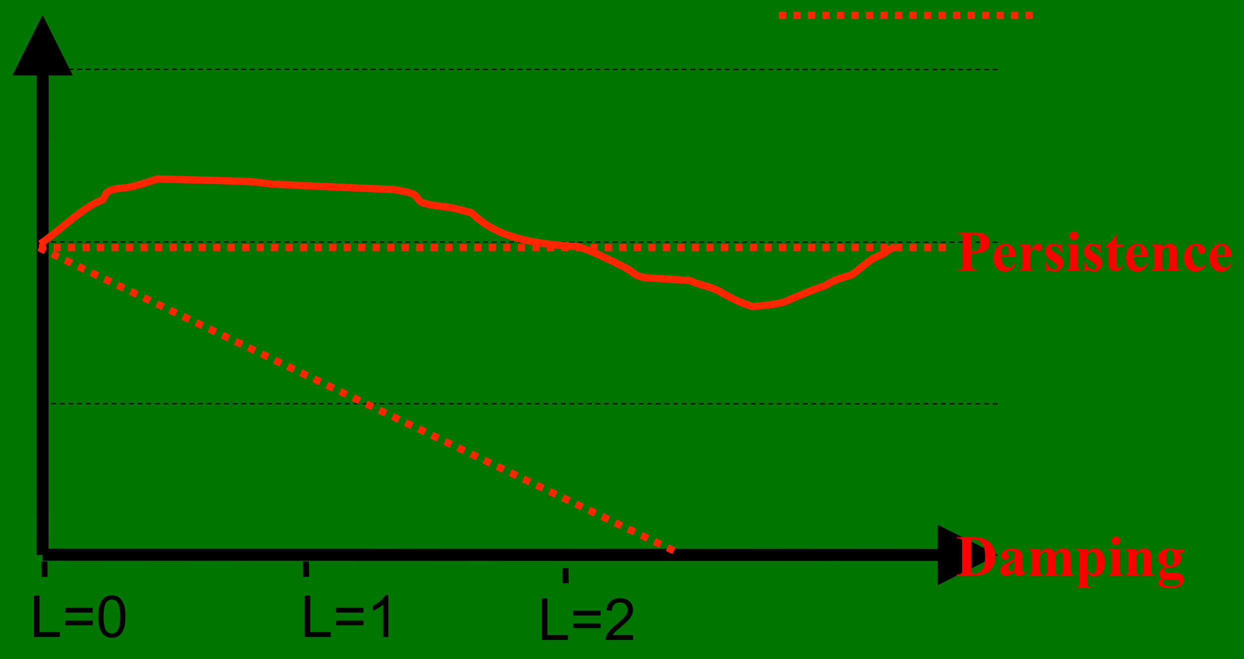


Correlation

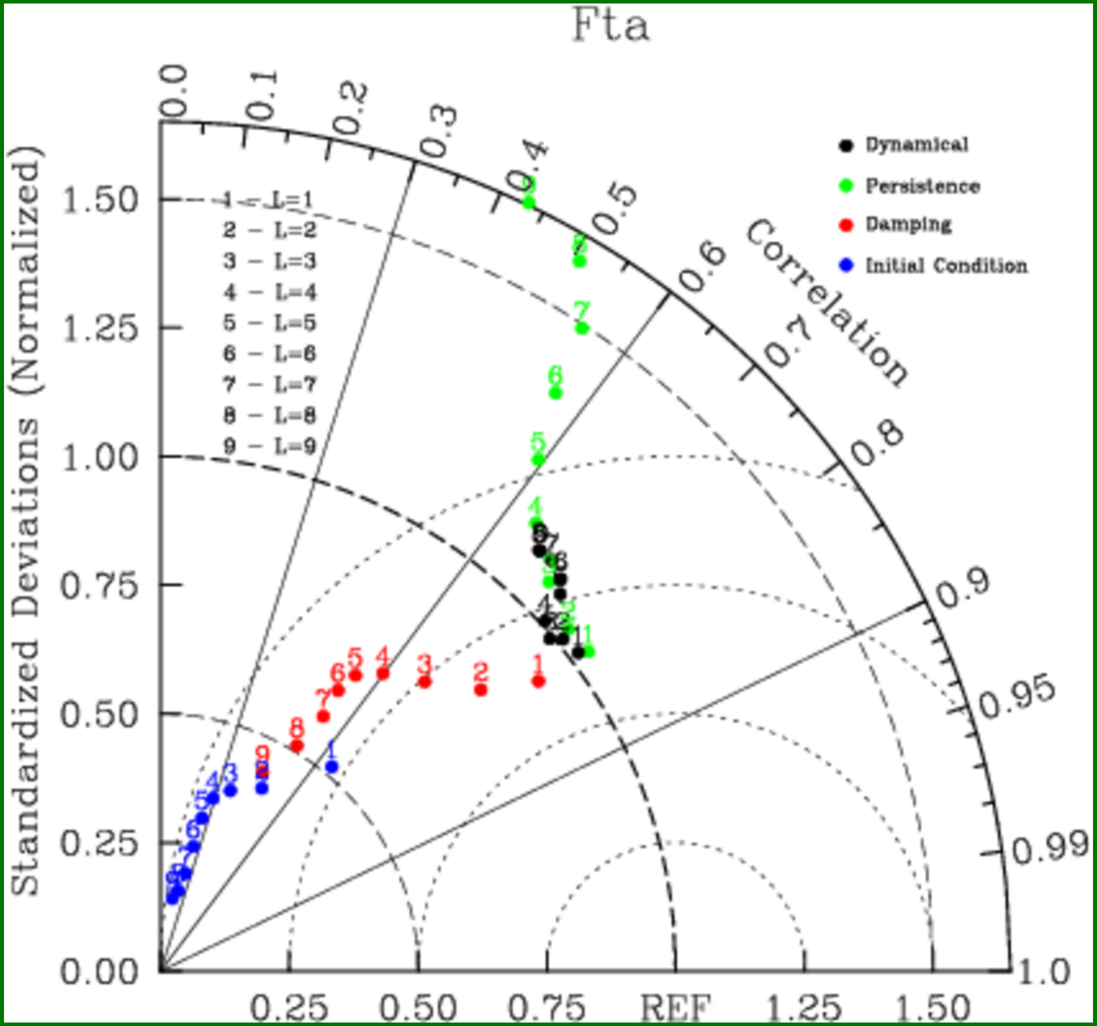
Regression

Benchmark Forecast:
Do we need dynamical forecast?

Relaxation or Damping of climate forcing
Anomaly at L=0 will persist or
damped to zero with decorrelation time scale.



Benchmark Forecast



The NCEP Climate Forecast System (CFS, Saha et al. 2006)

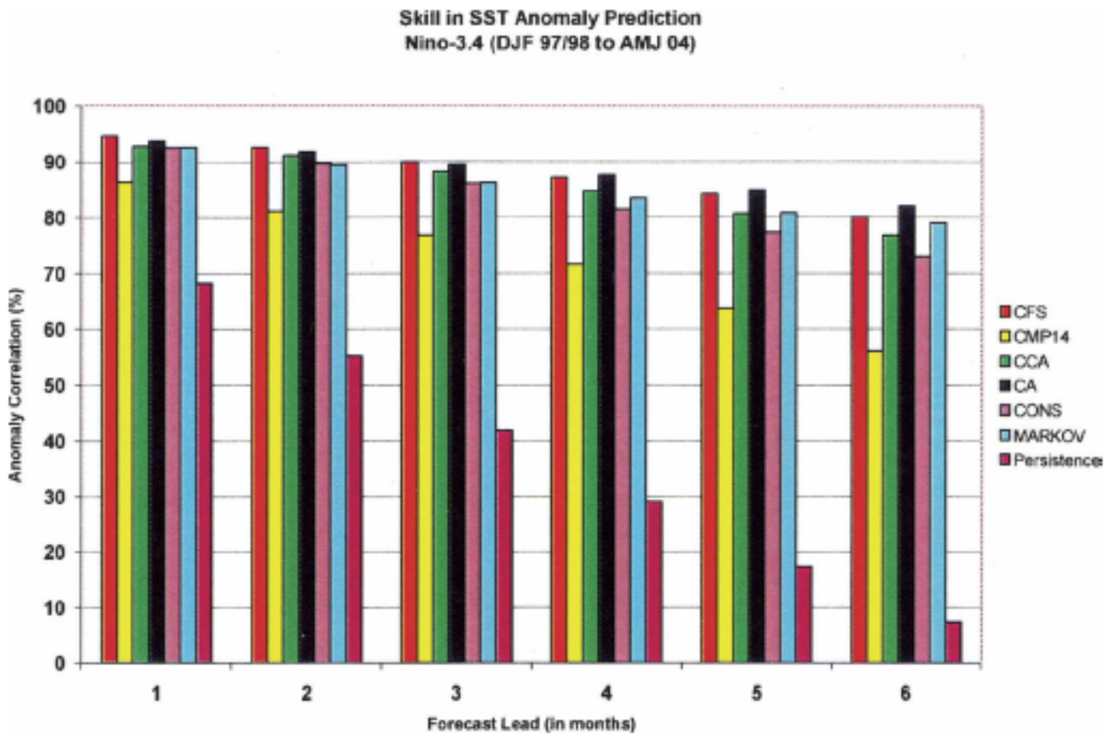
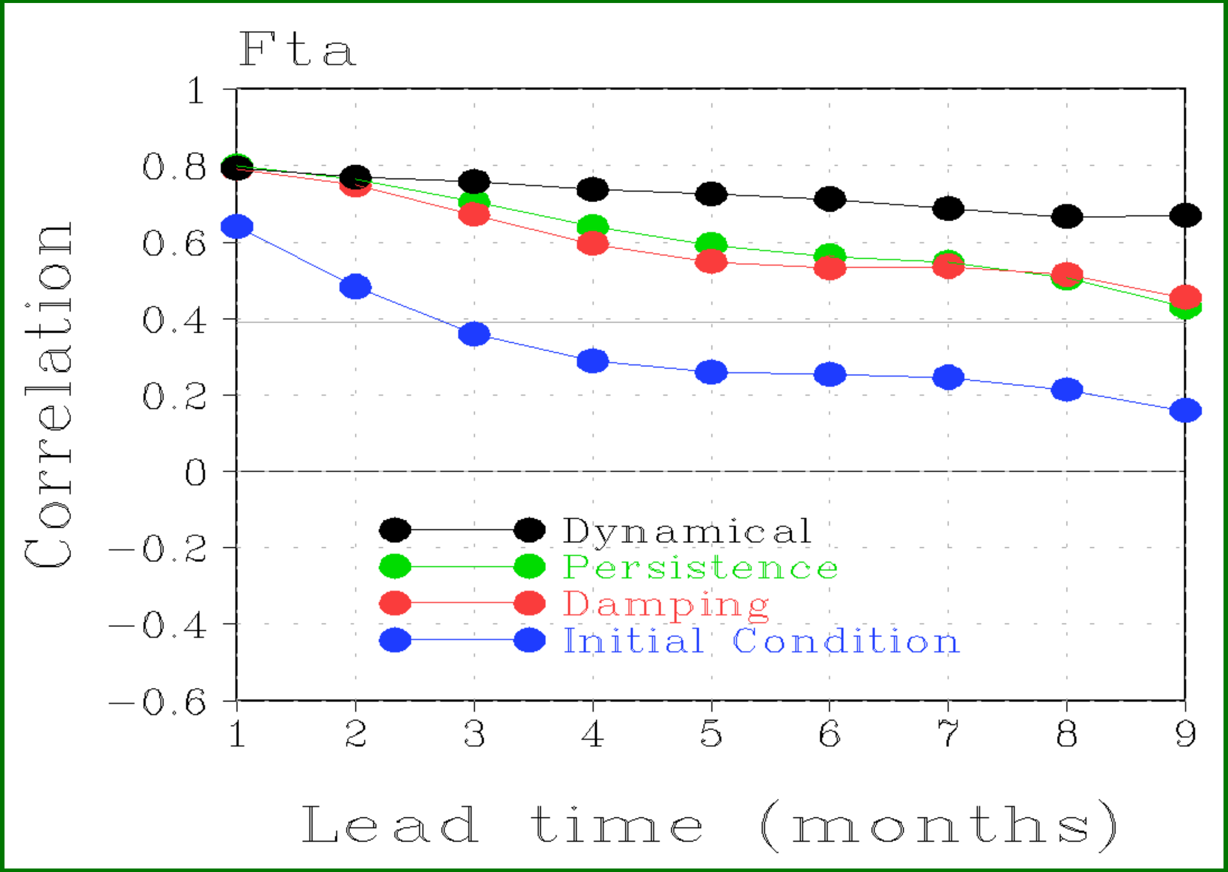


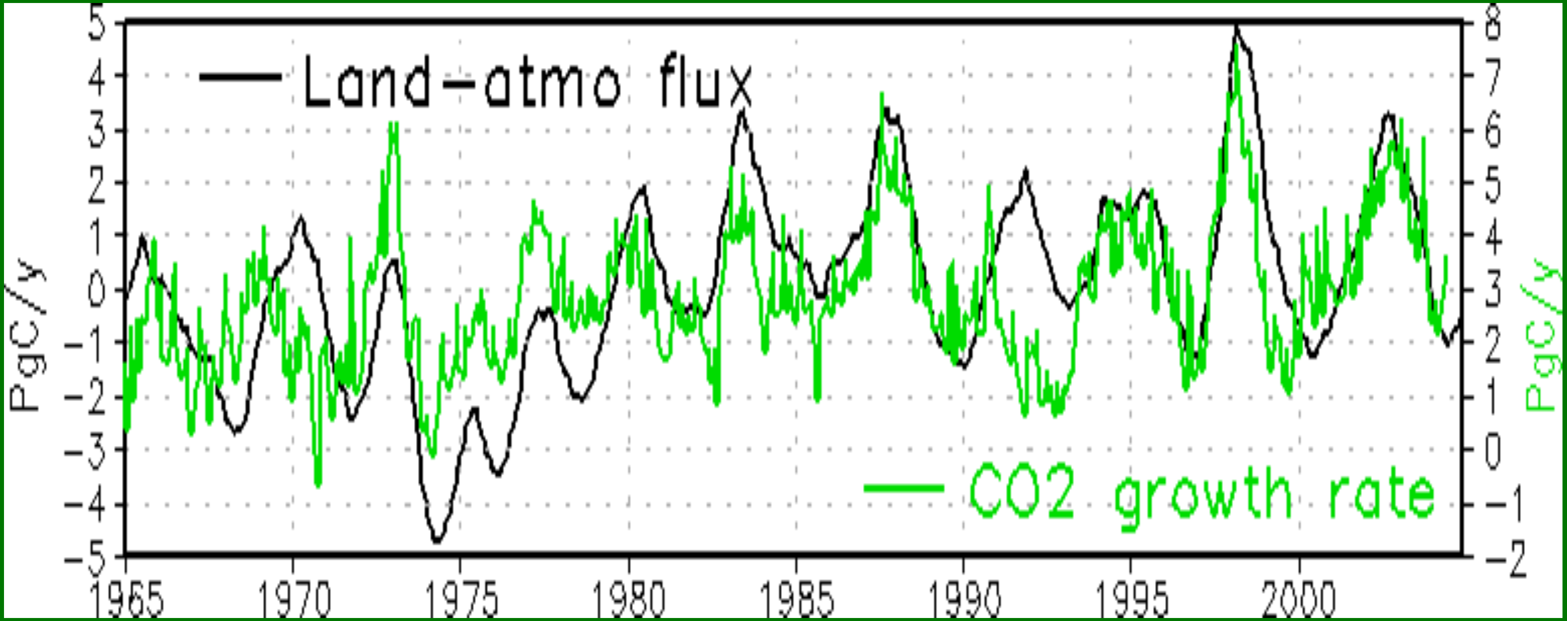
FIG. 2. Anomaly correlation (%) by various methods of the seasonal mean Niño-3.4 SST as a function of lead (horizontal; in months). The results are accumulated for all seasons in the (target) period DJF 1997/98 to DJF 2003/04. Except for CFS, all forecasts were archived in real time at CPC from 1996 onward. CMP14 is the previous coupled model, CCA is canonical correlation analysis, CA is constructed analog, CONS is a consolidation (a weighted mean), and MARKOV is an autoregressive method (see text for references).

Benchmark Forecast

Do we need dynamic forecast system?

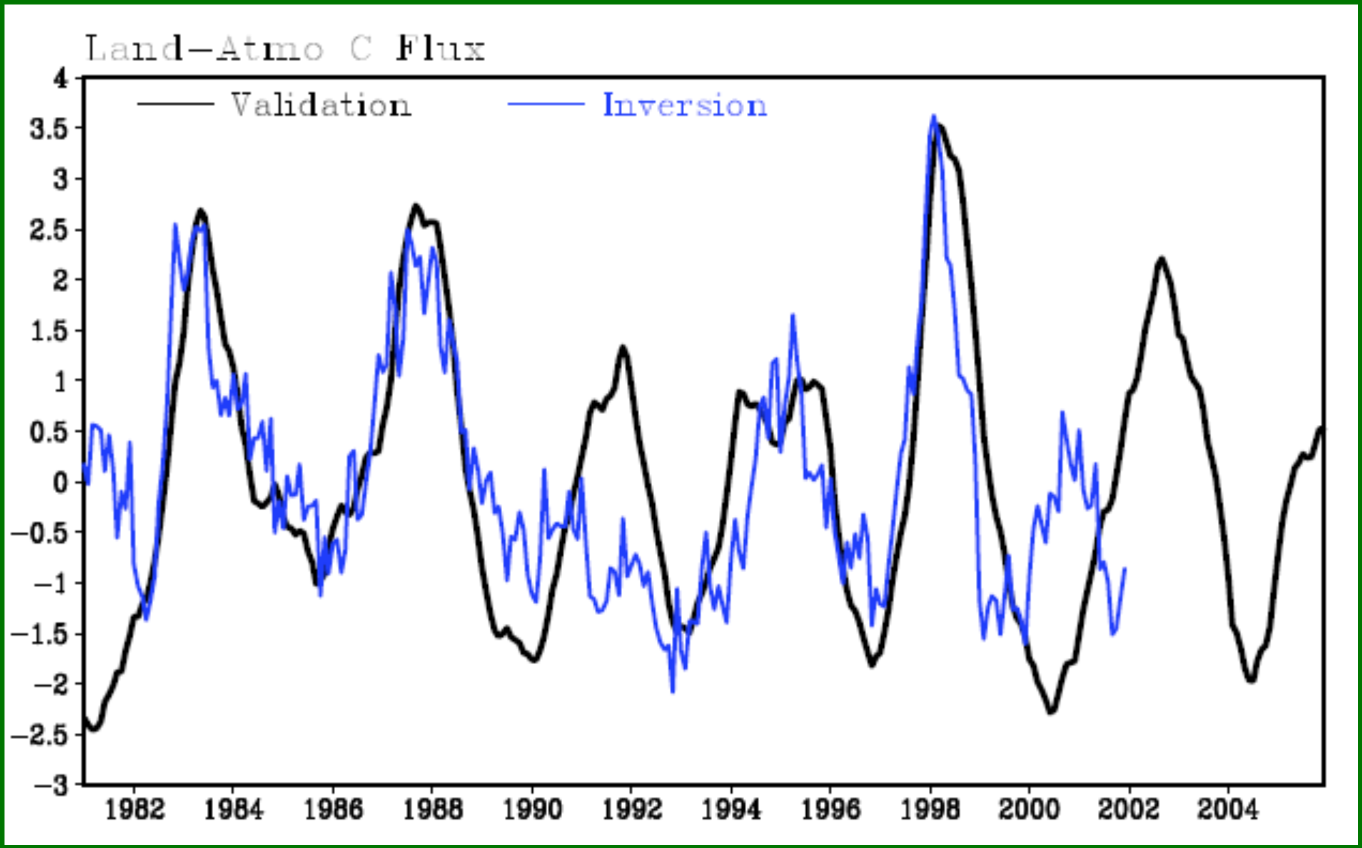


NEE('validation') and MLO CO2



NEE (land-atmo C flux): VEGAS forced by observed climate (Precip, T
This will be called 'validation' as there is no true observation availabl
Ocean contribution smaller, so NEE can be compared with atmo CO2
Using regression of inversion/OCMIP with Nino3.4/MEI?

NEE('validation') and Inversion (from MPI)



First Steps

Analysis of CO_2 record: ESRL
+ MODIS etc?

Forward models forced by a common climate data (P, T, …)

Emissions, ?

A web based forum?